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(54) Apparatus and method for an axially symmetric chemical vapor deposition reactor

(57) A reactor for chemical vapor deposition as illustrated in Fig. 2 has axial symmetry and the gas carrying the deposition materials is constrained to flow over the substrate with generally axial symmetry by means of a device 70 having a surface facing and substantially parallel to the substrate surface which has a multiplicity of apertures 74 for permitting the release of the gas with a generally uniform flow toward the substrate 10. Radiant heating lamps (50), above and below the substrate, provide uniform radiant heating for maintaining a uniform temperature during the deposition process on the substrate. The substrate (10) is supported on a pedestal (80) capable of adjusting the distance between the substrate and the region from which the gas, carrying the deposition materials is introduced. The pedestal can be rotated to provide additional uniformity of gas flow and heating with respect to the substrate surface.

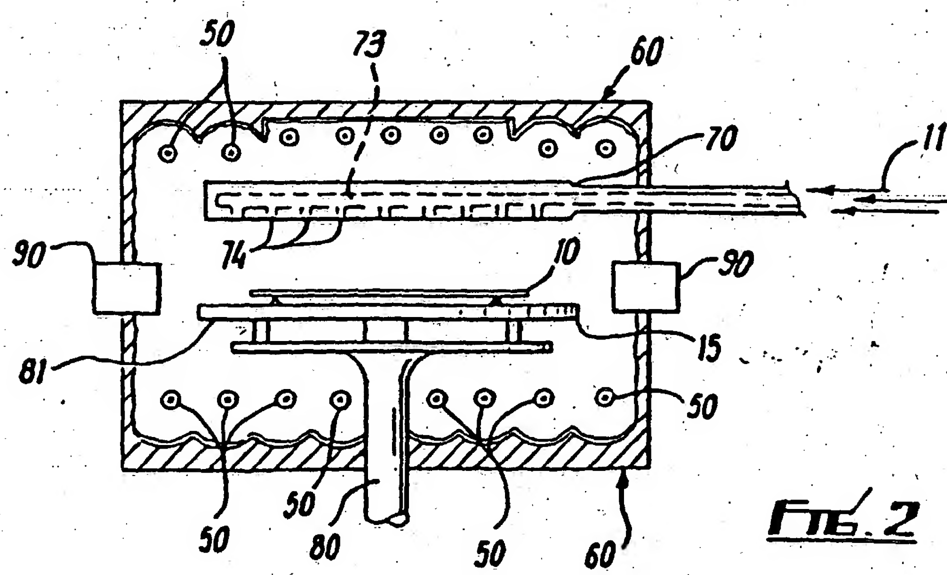
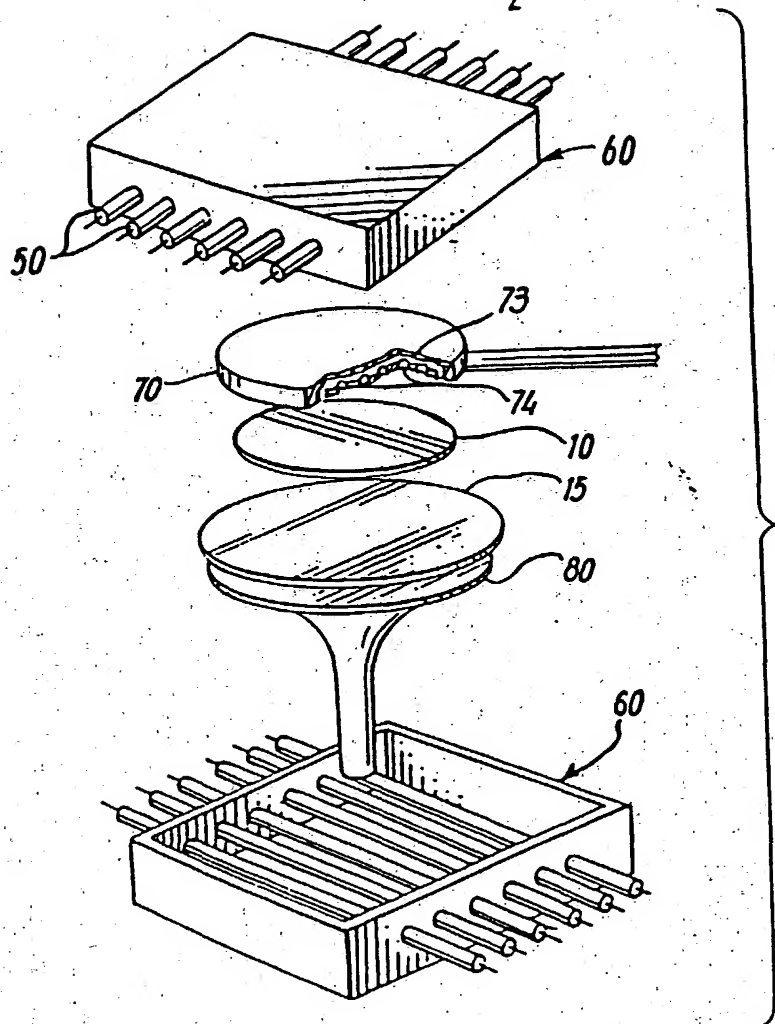


FIG. 2

GB 2 181 458 A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74
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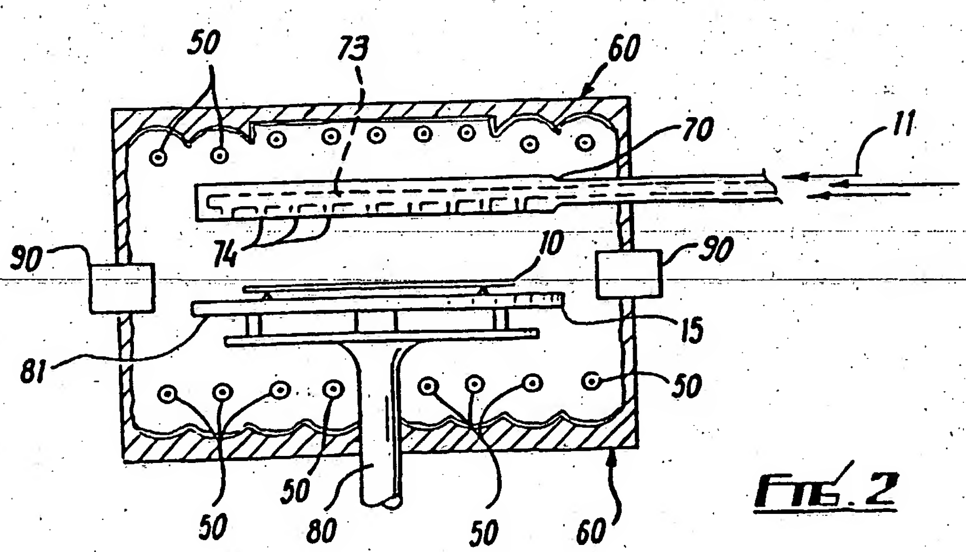
60

FIG. 1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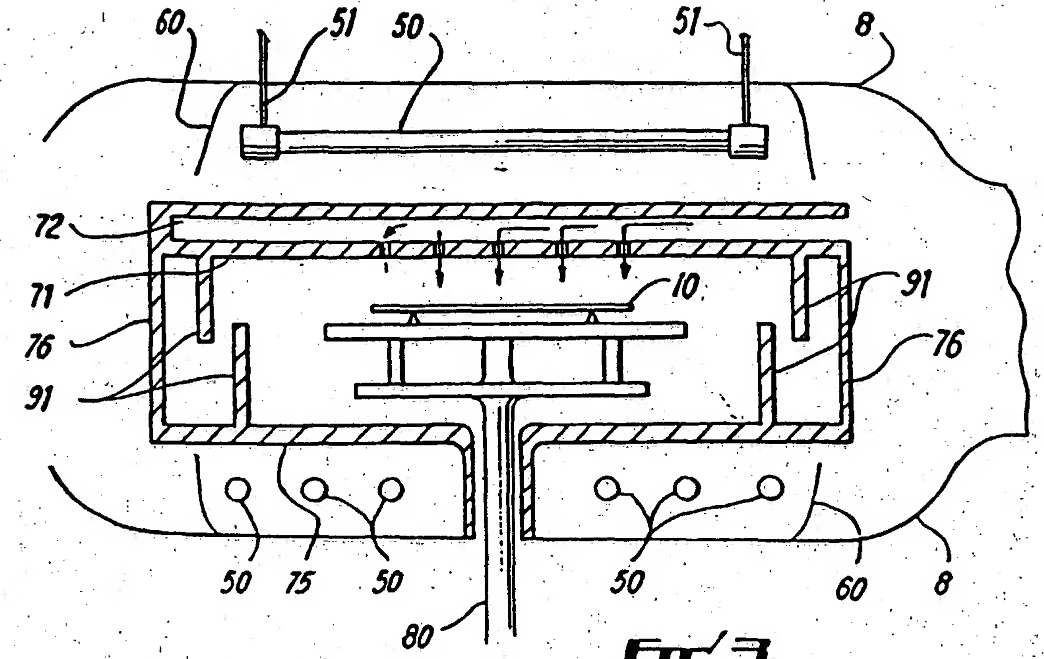
50
60

FIG. 2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8
72
71
76
91
10
91
76
50
75
50
50
60
8
80

FIG.3

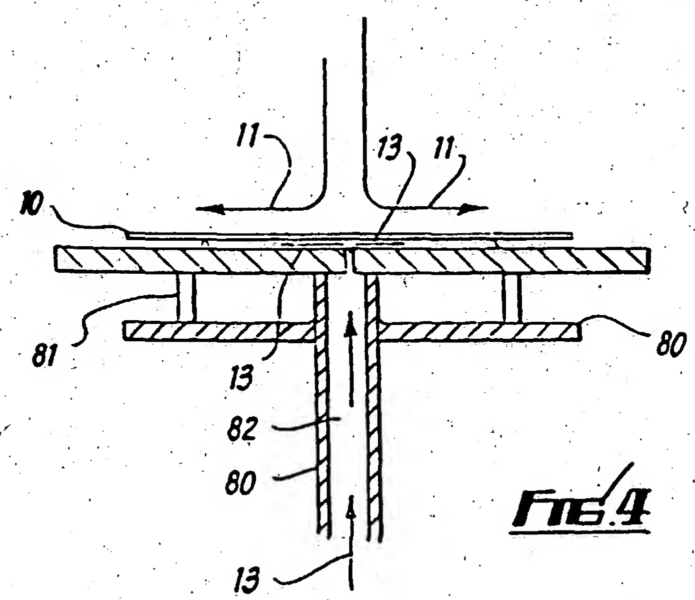
11
13
11
10
81
13
80
82
80
13

FIG.4

SPECIFICATION

Apparatus and method f r an axially symmetric ch mical vapor deposition reactor

This invention relates generally to the chemical deposition of a material carried by a gas onto a solid substrate and, more particularly, to a reactor for chemical vapour deposition that has axial symmetry.

It is known in the related art to provide for chemical vapor deposition of materials, such as epitaxial chemical vapor deposition, by conducting a gas containing the reactant materials over a solid substrate. The gas includes the material to be deposited on the substrates. The solid substrate must generally be held at an elevated temperature in order for the reaction with the surface to be sustained. Deposition can typically be accomplished within a container which causes the flow of gas across one or, more typically, a multiplicity of substrates that have been placed on a base or susceptor.

Several problems can arise in the prior art chemical vapor deposition reactors. Typically, the deposition reaction with the substrate removes vapor deposition materials from the flowing gas and results in a variation in reactant concentration in the gas. Because the gas is constrained to flow across a wafer substrate, the variation in concentration can result in an uneven deposited layer. This non-uniformity of deposition layers can occur for a plurality of substrates and can occur across a single substrate. In addition, systems in current use have a limited capacity for providing a uniform temperature for a plurality of substrates or even for a single substrate. Temperature uniformity is typically provided by having a large thermal mass associated with substrate. The large thermal mass and the associated thermal inertia can minimize non-uniformities in the temperature distribution of the substrates. However, the large thermal mass limits the rate at which the substrate can be brought to thermal equilibrium and consequently can have a detrimental effect on the time required for the processing of substrates. The large thermal mass, therefore, can have a direct impact on productivity.

Further, chemical vapor deposition reactors in current use for epitaxial deposition can permit autodoping, a doping of the deposition material resulting from dopant evaporation from the reverse side of th typically highly doped substrate. In prior reactors, care had to be taken to seal the reverse side of the substrate to prevent autodoping.

In an attempt to increase the productivity of chemical vapor deposition reactors, the reactors have been increased in size to accomodate mor substrate material. This increase in size has resulted in increased particulate contamination of the substrate. The particulate matter results from undesirable material deposits on the reactor walls, deposits that can detach from the walls and enter the deposition region.

In typical chemical vapor deposition systems, composition of the gaseous material, temperature and autodoping can be controlled, but additional control of the deposition process has been sought.

Recently, investigations have been made into the possibility of using an axially symmetric flow of gas over each substrate to provide a more satisfactory chemical vapor deposition process. With the axially symmetric flow and appropriate boundary conditions, a more uniform deposition layer can be obtained. Deposition on a single wafer permits flexibility in the method of heating, permitting heating and cooling times to be minimized. The axially symmetric gas flow has the additional benefit that autodoping, the undesired doping of the deposition layer by atoms from the highly doped substrate, can be minimized. In addition, the axially symmetric flow of gas permits larger substrates to be used, resulting in single wafer reactors. The single wafer reactors have tended to reduce particulate contamination of substrate deposition regions.

A need has therefore been felt for a chemical vapor deposition reactor that can take advantage of an axially symmetric gas flow and additionally can provide a uniform heating so that a small thermal mass can be associated with the substrate.

It is therefore an object of the present invention to provide an improved chemical vapor deposition reactor.

It is another object of the present invention to provide a chemical vapor deposition reactor for an axially symmetric substrate.

It is yet another object of the present invention to provide a chemical vapor deposition process having an axially symmetric geometry.

It is still a further object of the present invention to provide apparatus and method for uniformly heating a substrate having a circular geometry.

It is yet another object of the present invention to provide a reactor for chemical vapor deposition having apparatus capable of providing additional control of the deposition process.

It is a still further object of the present invention to provide a vapor deposition reactor for which the flow of gas carrying the reactant mat rial ov r the substrate has axial symmetry.

According to the present invention a reactor for chemical vapor deposition onto a heated substrate comprises:

substrate means having a circular configuration;

heating means for uniformly heating said substrate means; and

gas flow means for providing an axially

symmetric flow of gas acr ss said substrat means.

A preferred embodiment incorporates apparatus having a circular reaction chamber for chemical vapor deposition of materials on a generally circular substrate. The circular substrate is supported on a base or susceptor by a pedestal. Gas carrying the material to be deposited on the substrate is directed toward the substrate surface with generally uniform magnitude of velocity perpendicular to the substrate surface, by apparatus located at a controllable distance from the substrate. The gas is generally constrained to have an axially symmetric flow over the surface of the substrate. Radiant heating apparatus is provided t heat the substrate and associated apparatus to a uniform temperature. The uniformity of the temperature provided by the heating apparatus permits the substrate and associated apparatus to have a relatively small thermal mass. The small thermal mass permits thermal equilibrium to be attained rapidly for a selected substrate temperature. The pedestal supporting the substrate can be rotated for additional temperature and deposition uniformity. An additional flow of gas can be introduced to minimize autodoping of the deposited layer.

The invention is further described by means of example and not in any limitative sense with reference to the accompanying drawings, of which:–

Figure 1 is an exploded schematic view of the inventive vapor deposition reactor chamber;

Figure 2 is a schematic cross-sectional view of the invention vapor deposition reactor chamber;

Figure 3 is a schematic cross-sectional view of the inventive reactor chamber showing additional detail of the preferred embodiment; and

Figure 4 is a cross-sectional view of the pedestal for providing an additional flow of gas to minimize autodoping of the material deposited on the substrate.

Referring now to Fig. 1, an exploded perspective schematic view is shown of the apparatus comprising the chemical vapor deposition chamber of the reactor, the apparatus of the reactor chamber includes an upper and a lower heating chamber 60. The two chambers have associated therewith a plurality of radiant heating elements 50. These heating elements are typically elongat d lamps, while the individual chambers can be typically square in shape in the preferred embodiment. As will be clear, other chamber geometri s can be used. The lamps are inserted through apertures in the chamber walls and are generally p sitioned parallel to the other lamps in and l cated in a plane parallel t the substrate 10. Th upper and l wer chambers are g nerally arranged so that the assembly of lamps of each chamber is at a right angles to the other assembly of lamps. The substrate 10 and associated susceptor 15 are supported in the reactor by a pedestal 80. The gas 11 carrying the materials to be deposited on substrate 10 is introduced into the reactor chambers by device 70. Device 70 is generally comprised of quartz (for transmission to the heating radiation) and includes a chamber into which gas 11 is introduced. The device 70 has a surfac facing and substantially parallel to the substrate surface. This surface has a multiplicity of apertures for permitting the release of the gas with a generally uniform flow toward the substrate.

Referring now to Fig. 2, a cross-sectional view of the chemical vapor deposition reactor is shown in cross-section. The lamps 50 in the two heating chambers 60 provide a uniform heating for the substrate 10 and associated susceptor 15, the lamps 50 are not shown as being at right angles in Fig. 2 to illustrate two heating lamp configurations. In the lower heating lamp configuration, parabolic reflections direct the radiant energy toward susceptor 15 and associated substrate 10. In the upper chamber 60 of Fig. 2, the outer heating lamps 50 have parabolic reflectors associated therewith. The inner heating lamps are located in front of a planar region 52. The planar region and the parabolic reflectors have highly reflective material coated thereon to direct the radiation toward the substrate-susceptor combination. The substrate/susceptor combination is supported by a pedestal 80, and although not shown in Fig. 2, the base of the pedestal extends through a heating chamber 60. The device 70 for supplying the gas containing the deposition material to the substrate has an inlet for receiving gas 11 and a plurality of apertures 74 for uniformly directing the gas to the substrate 10. Apparatus 90, not shown in detail, is apparatus for extracting the gas from the deposition chamber in a manner to preserve the axial symmetry of the flow of gas. Apparatus 90 can include a plurality of apertures, the main function being the control of the flow of gas. Apparatus 90 also provides a source of thermal loss comprising the uniformity of the temperature across the substrate-susceptor combination.

Referring next to Fig. 3, a more detail d implementation of the reactor chamber is shown. The chambers 60 include lamps 50 that are electrically and mechanically coupled to the remainder of the apparatus by coupling apparatus 51 and can have reflecting region associated therewith as shown in Fig. 2. Device 70 includes a first plane of material 72 and a second plane of material 71. The plane of material 71 is generally parallel to the substrat 10 and has a plurality of apertures for directing gas 11 toward the substrate Substrate 10 is supported by pedestal 80. The gas is constrained to flow past a plurality of

baffles 91, to maintain an axially symmetric flow. Th substrat and upper portion of the pedestal are generally enclosed by plate 71, plate 75 and outer surfaces 76 for restricting th flow of gas. The gas can also be extracted from the enclosure through a plurality of apertures. Housing 8 is coupled to the heating chambers 60 and has additional apparatus, not shown, for coupling to the upper and lower portions of the reactor components and for supporting the internal enclosure apparatus.

Referring to Fig. 4, a procedure for inhibiting autodoping of the deposition layer is shown. The axially symmetric flow of gas 11 flows outward toward the edges of the substrate 10. The substrate 10 is supported above susceptor 15 by spacers 16. The susceptor is supported above the pedestal 80 by risers 81 and by the vertical walls of the pedestal 80. A gas 13 flows through a passage in the pedestal 80, through an aperture 83 in the susceptor 15 to the space between the susceptor and the substrate. This radially outward flow, in conjunction with the radially outward flow of the carrier gas 11, carries undesired substrate dopant atoms away from the deposition portion of the substrate.

the structure of the chamical vapor deposition reactor is designed to take advantage of the beneficial effects of an axially symmetric flow of carrier gas over a substrate. This gas flow configuration, also referred to as stagnation point flow, provides advantages of radial uniformity of concentration of deposition materials in the vicinity of the substrate, radial uniformity of the temperature isotherms in the gas above the substrate surface, and radial uniformity of rates of chemical reactions in the gas and on the substrate surface.

The device 70, which in the preferred embodiment can consist of plates of material with apertures in the plate nearest the substrate, provides a convenient technique for introducing the axially symmetric gas flow into the chamber. In the preferred embodiment, the apertures are located at the vertices of equilateral angles. Apparatus such as the baffles 91, are provides to insure that the process of extraction of carrier gas does not appreciably disturb the axially symmetric flow of gas. The devices 70 is typically constructed of a material capable of transmitting a large fraction of radiation to the susceptor-substrate combination.

The heating chambers are similarly implemented to support the axial symmetry of the deposition and to maintain a uniform temperature over the substrate. The plurality of lamps 50 are disposed within the heating chambers. The walls of chambers 53 as well as th reflecting region 52 and parabolic reflections 51 hav deposited thereon a high-reflectivity material to enhance th rmal efficiency and t increase the area of virtual heat sources seen by the substrate resulting. Referring for example to Fig. 2, the edge of the substrate is not exposed to the same radiation as the remainder of the substrate because of the lack of heating sources in the direction of region 90. To compensate for this cooler environment, the outermost heat lamps can be operated with additional power, thereby increasing the radiation heating in the region. Varying the positions of the heating elements, making the outermost heat lamp assemblies can be tiltable, or extending the heating chamber well beyond the substrate, can also be used to compensate for the increased losses of heat of the exterior region of the substrate. The sides of the heating chamber can be provided with highly reflecting material, providing the effect of additional heat sources as seen from the substrate because of reflected radiation. The orientation of the heat lamps is rotated with respect to the orientation of the heat lamps in the other chamber to reduce further the structure resulting from use of discrete heat sources. The pedestal supporting the substrate can be rotated to provide further reduction in any remaining thermal structure.

Fig. 4 illustrates an embodiment of the present invention in which a flow of gas 13 can be used to reduce autodoping. The flow of gases 11 and 13 causes dopant materials, evaporated from the underside of the substrate, to be carried away from the surface of the substrate receiving the deposited materials. The pedestal is typically composed of a material transparent to a large portion of the spectrum of the heating radiation.

Thinning or eliminating of the susceptor supporting the substrate can reduce the mass that must be heated to reach thermal equilibrium. By reducing the thermal mass, more substrates can be processed in a given time and greater productivity can be achieved.

The substrate can be conveniently moved up or down relative to the plate through which the carrier gas is introduced. This flexibility in positioning provides an additional control of the deposition conditions.

A further source of non-uniformity is the radiation field experienced by the susceptor-substrate combination because of the adsorption characteristics and temperatures of the device 70, the pedestal and any other structural members that must be interposed between the radiation sources and the substrate-susceptor combination. Account must be taken of the perturbations resulting in the radiation field resulting from the presence of those elements such as thermal influence of the structural members resulting from absorption and emission of radiation.

The above description is included to illustrate the operation of the preferred embodiment and is not meant to limit the scope of the invention. The scope of the invention is t be limited only by the following claims. From

the foregoing description many variations will be apparent to on skilled in the art that would yet be encompassed by the scope of the invention.

CLAIMS

1. A reactor for chemical vapor deposition onto a heated substrate comprising:
substrate means having a circular configuration;
heating means for uniformly heating said substrate means; and
gas flow means for providing an axially symmetric flow of gas across said substrate means.

2. Chemical vapor deposition reactor of claim 1 further including support means for supporting said substrate means, said support means permitting a distance between said gas flow means and said substrate means to be controlled.

3. The chemical vapor deposition of claim 1, further including support means for supporting said substrate, said support means capable of rotating said substrate.

4. The chemical vapor deposition reactor of claim 1, wherein said gas flow means includes apparatus for introducing said gas with a uniform velocity directed perpendicular to a surface of said substrate.

5. The chemical vapor deposition reactor of claim 1, wherein said heating means includes a first and a second chamber, at least one of said chambers including a plurality of heat lamps.

6. The chemical vapor deposition reactor of claim 5, wherein said chambers have at least a portion of interior walls coated with a high-reflectivity material.

7. The chemical vapor deposition reactor of claim 1, wherein said axially symmetric flow of gas permits a stagnation point gas flow configuration.

8. The method of chemical vapor deposition comprising the steps of:
configuring a uniform substrate;
heating said substrate uniformly to a predetermined temperature; and
flowing a gas past said substrate, said gas flow having axial symmetry, wherein said gas includes materials for deposition on said substrate.

9. The method of chemical vapor deposition of claim 8 further comprising the step of rotating said substrate.

10. The method of chemical vapor depositi n of claim 8, further comprising the step of introducing a second gas flow past a second surfac of said substrate to minimize autodoping.

11. The method of chemical vapor deposition of claim 8, wherein said fl wing gas step includes producing a stagnation point gas flow with respect to said substrate.

12. A reactor for chemical vapor depositi n comprising:
a circular substrate;
a chamb r having a plurality of apertures, said apertures generally having axial symmetry with respect to and generally uniformly distant from said substrate;
a plurality of heating lamps providing g nerally uniform temperature in said substrate; and
at least one aperture disposed generally symmetrically about a periphery of said circular substrate.

13. The chemical vapor deposition reactor of claim 12 wherein said chamber is fabricated from a material permitting radiation to pass therethrough.

14. The chemical vapor deposition reactor of claim 12 further including aperture means beneath said substrate for introducing a second flow of gas to said substrate.

15. The chemical vapor deposition reactor of claim 12 wherein said heating lamps are disposed above and/or below said substrate.

16. The chemical vapor deposition reactor of claim 12 wherein said substrate is supported by a susceptor.

17. The chemical vapor deposition reactor of claim 12 wherein said chamber and said at least one aperture are configured to provide a stagnation point flow of gas.

18. The chemical vapor deposition reactor of claim 12 further including a first heating chamber positioned on a first side of said substrate and a second heating chamber positioned on a second side of said substrate, said first and said second heating chambers including said plurality of heating lamps, said first chamber heating lamps generally disposed at right angles to said second chamber heating lamps.

19. The chemical vapor deposition reactor of claim 12 further including means for rotating said substrate.

20. A chemical vapor deposition reactor substantially as hereinbefore described with reference to the accompanying drawings.

21. A method of chemical vapor deposition substantially as hereinbefore described with reference to the accompanying drawings.

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